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TECHNICAL REPORT

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FOURTH ANNUAL TRI-SERVICE CONFERENCE on the BIOLOGICAL EFFECTS OF MICROWAVE RADIATION

BY

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FOURTH ANNUAL TRI-SERVICE CONFERENCE
on the
BIOLOGICAL EFFECTS OF MICROWAVE RADIATION

INTRODUCTION

This document should be regarded as a preliminary and even cursory report of the Fourth Tri-Service Conference on Microwave Hazards. A complete report with verbatim presentations of each paper and all floor discussions will be published within a few months by the Ad Hoc Committee on Microwave Hazards. This formal report, when published, will be available from the Committee which has headquarters at the Rome Air Development Center, Rome, New York. While it is not customary for this Office to report on meetings held in the United States, it is felt that there are a number of laboratories in Europe and America which might be interested in obtaining these preliminary impressions prior to the publication of the formal proceedings which will probably require several months.

The purpose of the present report is to provide a general impression of the attitude towards potential hazards as evinced by the scientists and safety personnel intimately concerned with the problem. Several very interesting papers are not included, as, for example, Dr. Schwan's work on the "pearl-chain" formation of lipid globules in aqueous suspension under the influence of microwave radiation. It is believed that this highly technical work could not be adequately presented in abstract form and furthermore would not be immediately applicable to the practical problem of assessing radar hazards to personnel under current operating conditions. Several other papers, particularly those dealing with instrumentation and measurement methods, are also omitted for the same reason.

It will also be noted that many of the authors presenting papers at this meeting did not give power levels utilized in their experiments and, in some cases, did not specify the frequencies of the radiation used. It should be born in mind that their experiments utilized power levels many times greater than the current limit of .01 watt/cm^2 which is used for safety purposes. Their studies did, however, compare experimental and control animals to the same fiducial points (such as similar temperature rises, equal distances from the same equipment, etc.). It should be realized, of course, that even scientists who specialize in the measurements of field intensities are in disagreement concerning some of the particular parameters and are themselves engaged in the development of instruments for such measurements.

ABSTRACTS of PAPERS

The introductory welcome was made by Col. George M. Knauf (Patrick Air Force Base) who is also the Chairman of the Tri-Service Ad Hoc Committee on Microwave Hazards. Col. Knauf reviewed the background of the studies of these hazards and stated the arbitrary nature of the current limiting exposure rate of .01 watt/cm^2. Obviously, since different frequencies are absorbed by bio-

logical tissues in varying degrees, any such limit must be based on the most easily absorbed radiation, thereby giving it even greater safety factors for less easily absorbed frequencies. Even though this limit is an arbitrary one, the work reported during the past four years has given no indication that this figure needs revising.

LCDR F. E. Edmunds, USN (Bureau of Ships), discussed the peculiar problem facing the Navy in dealing with radar. Unlike the other services, the Navy does not have available aboard ships great distances which can allow a transmitting antenna to be placed in remote places away from crowded areas. In order to keep personnel exposures below the arbitrary "Safe" limit of .01 watt/cm^2, it has been necessary to consider the integral energy dose received over a period of time, so that the summation of energy received in the pulses, when divided by the exposure period, will result in a power per unit area of less than the stated limit. This problem is further complicated in shipboard life by the fact that some vessels may have several radar equipments operating simultaneously.

Dr. Harry R. Meahl (General Electric Company) discussed the basic problem of measuring RF field strength. He also stated that the output of various emitting systems was a series of harmonic frequencies and was not limited to a single fundamental frequency. For this reason, existing RF field strength meters do not work for microwave radiations emitted by various radars. As a further complication, the refraction and reflection of microwave radiations result in the intensification of the field strength in certain areas which cannot be explained by existing theory. This is particularly true in the case of multiple sources of radiation such as that commonly found aboard Naval vessels.

A.P. DeMinco (Rome Air Development Center) called attention to an added hazard existing near high-powered radars as a result of the X-rays emitted by klystron and magnetron tubes, which have an energy range from 400 to 800 KeV. There is at least one case on record in which maintenance personnel removed the shielding, normally placed around such equipment, for repair work and thereby received doses of X-irradiation sufficient to cause erythema and certain alterations in the blood picture.

Dr. S. A. Gunn (University of Miami) reported on the effects of 24,000 megacycle radiation on the male endocrine system of the rat. In particular, the testes of these rats were exposed to this radiation, and subsequent histological examination of the germinal tissue was made. One of the first effects noted was severe burning of the scrotal epidermis. Subsequent microwave exposures were made with a thermocouple embedded deep in the testis, as well as parallel exposures utilizing infrared radiation. It was reported that radiation sufficient to cause the same rise in temperature (at the center of the organ) resulted in a very marked degeneration of the seminiferous tubules in the case of microwave, whereas no detectable damage was noted at the same temperature following infrared radiation. This was interpreted by the authors as an argument for a specific effect rather than thermal. The questioning from the floor, however, indicated that some observers consider the possibility that temperature increases as a function of depth may be distributed quite differently in the two cases, and that a single thermocouple

reading at the center may not be indicative of the mean temperature throughout the whole organ. This, in conjunction with the severe surface burns, caused many to suspect that, even in this case, thermal effects must be considered.

Lt. Col. S. A. Bach (Army Medical Research Laboratory, Fort Knox) reported on certain electrophoretic studies of gamma-globulin. While it is possible to alter the electrophoretic mobility curves of gamma-globulins with sufficiently high doses of microwave irradiation, the most interesting thing presented by the Fort Knox Laboratory was the fact that an increase in antigenic titre has been observed in gamma-globulin exposed to microwave radiation levels which are too low to produce any alterations in the mobility pattern. Whether or not this constitutes sufficient evidence to claim that no molecular reorientation has occurred is now under study. It is planned to investigate samples exhibiting increase titre by ultracentrifugal sedimentation and by intrinsic viscosity methods.

Dr. Paul O. Vogelhut (Univ of California) has been studying the kinetics and thermodynamics of protein rearrangements under microwave irradiation. Although this work is still in progress, present indications are that the free energies of such reactions are characterized by lower values than are commonly observed in most thermochemical systems. This constitutes one of the best arguments in favor of specific microwave effects as opposed to the most commonly held view that these effects are thermal in nature.

Dr. C. M. Osborn (Univ of Buffalo) presented an interesting series of results obtained in dogs exposed to 200 megacycle radiation. His studies tend to indicate that the lethal result is obtained in the average case when body temperature is raised 9°F for a period of 15 minutes for the frequency of 200 megacycles. This is usually obtained by an exposure of 330 mw/cm^2. It should be pointed out that this result is obtained in dogs oriented perpendicular to the direction of the field and that a shorter time (with consequent higher body temperature) is required for dogs oriented parallel to the field direction. Although the above finding is for the average case (the point at which 50% mortality occurs), a study of the minimum conditions resulting in death have been observed to be a 7 or 8°F increase in rectal temperature for a period of ten minutes.

Dr. Gordon W. Searle (Univ of Iowa) presented a paper on the effects of 2450 megacycle microwaves on mammals and on the larvae of the common fruit fly. Perhaps his most interesting point was the fact that the larvae can be killed or their development altered in various ways by microwave radiation. However, when the temperature of the larvae during the radiation episode is kept at a carefully controlled normal, the same level of radiation produced no observable effects.

Drs. Joseph B. Flemming and R. D. McAfee (Tulane University) presented similar results from their study with peripheral nerve activity in decerebrate cats. Their results indicated that certain peripheral nervous responses occur when the temperature of these nerves is raised to 45°C. While there may be selective heating of these fibers (or of the whole layer of tissue at the depth below the skin at which these fibers exist), the maintenance of

normal skin temperature during the exposure episode resulted in no observable effects.

Dr. J. W. Howland (University of Rochester) presented a study with dogs of which half had been previously exposed to X-irradiation. To date, only a small number of paired controlled experiments have been conducted, but present results seem to indicate that dogs which have recovered from a previous exposure to X-rays seem more resistant to microwave irradiation. In both types of dog, survival is increased if drinking water is permitted at liberty. For this and other clinical reasons observed in his laboratory, he believes that the harmful and sometimes lethal effects of massive exposure to microwave radiation are due almost entirely to heating.

Dr. L. O. Merola (Tufts University) presented some evidence on biochemical changes in the lenses of rabbit eyes in which cataracts had been formed by microwave radiation. Particular attention was paid to the content of sodium and potassium ions, and it was found that the concentration of sodium was increased concomitant with cataract formation, while the concentration of potassium decreased. Since the latter was a more pronounced effect, the total concentration of sodium plus potassium showed a marked decrease. The first sign of damage in lenses exposed to microwave radiation is a significant drop in ascorbic acid content. Glutathione, which is also present in the normal lens in great quantities, is not changed significantly.

Drs. M. Zaret and M. Eisenbud (New York University) presented the results of a statistical study of lenticular effects of microwaves among humans. It was emphasized that all human lenses have some imperfections in the way of opacities and cloudy areas. While no sharp line can be drawn which categorically separates a "normal" opacity from an "abnormal" one, most clinicians make their decisions on the basis of a matter of degree; and in general, if the patient himself is not aware of any difficulty, he is considered normal. On the basis of studying both exposed and unexposed personnel, the investigations concluded that no late-stage lens defects were found to be pathognomic to microwave exposure. However, some early-stage defects (undetected by the subjects themselves) were found statistically to be slightly more numerous in the exposed group.

SUMMARY

Colonel Knauf reviewed and summarized the meeting. In his opinion, in which most of the attendees seemed to concur, there is no insurmountable hazard problem existing with current radars. While it is true that profound and even lethal results can be produced experimentally by application of massive microwave energy to biological systems, the receiving of such doses by radar personnel trained in very simple precautions would be extremely rare if not virtually impossible. Although there have been some accidents involving humans in the past, these have usually resulted among personnel who made manual adjustments of components immediately in the near-field beams of large radars and,

in some cases, from X-ray exposure ensuing after the removal of the shield around large klystron or magnetron tubes. Some confusion has also resulted from the construction of a special radiation-resistant suit for the protection of radar personnel, but Knauf's summary explained that this suit was designed for use exclusively under rare emergency conditions in which maintenance work on large antennae must be accomplished when it would not be feasible to turn the power off. It was concluded that the old arbitrary limit of .01 watt/cm^2 was still a reasonable figure to use for safety standards, inasmuch as the deleterious effects described during the conference required the application of power many times greater than this in order to produce observable effects. Furthermore, the more serious consequences (if not all) seem to be occasioned when there was a pronounced rise in temperature, and this effect in itself should be detectable by exposed personnel themselves. It was also believed that the observance of a few simple safety regulations, such as staying out of the near-field beam during operation of the set, should be sufficient to preclude hazardous situations.